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(54) **INTERNAL COMBUSTION ENGINE SYSTEM, CONTROL METHOD THEREOF, AND VEHICLE**

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F02D 41/22	(2006.01)
F02D 43/00	(2006.01)
F02M 25/07	(2006.01)
F02B 47/08	(2006.01)
F01N 3/24	(2006.01)

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,014,203	A *	5/1991	Miyazaki et al.	701/108
5,979,160	A *	11/1999	Yashiki et al.	60/277
6,701,232	B2 *	3/2004	Yamaki	701/33
7,150,144	B2 *	12/2006	Nakagawa et al.	60/277
7,716,920	B2 *	5/2010	Onodera et al.	60/285

(Continued)

FOREIGN PATENT DOCUMENTS

JP 06058197 A * 3/1994 .... 701/108

(Continued)

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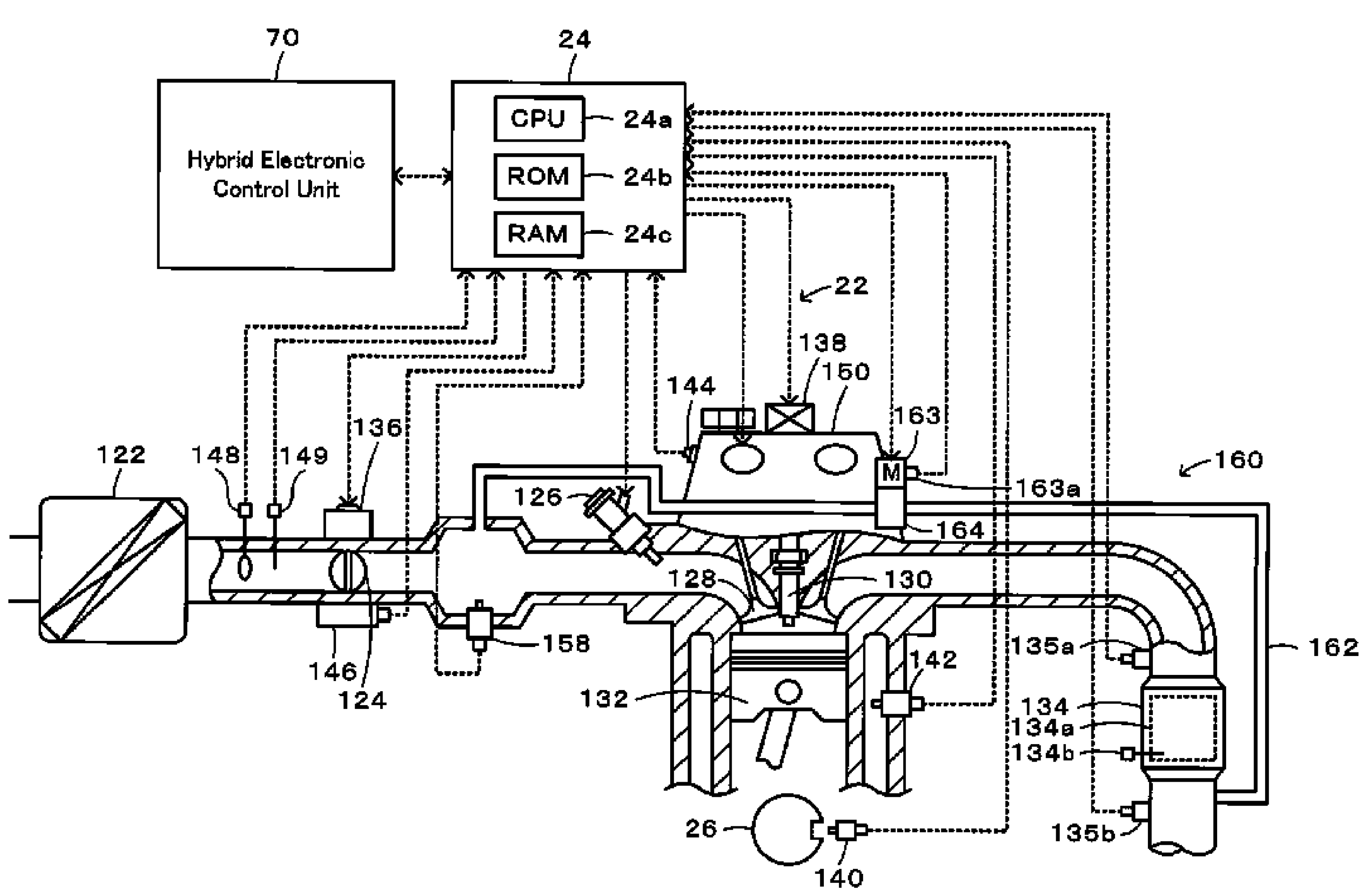
(57) **ABSTRACT**

Upon no detection of the closing abnormality where the EGR valve does not become in the totally closed state (when the flag Fa is value ‘0’), the engine is controlled using the target fuel injection amount obtained from the correction of the basic fuel injection amount toward the increase direction, in the case that the engine is operated together with the recirculation of the exhaust in the preset high-load operation range (when the flag Fi is ‘1’). Upon detection of the closing abnormality (when the flag Fa is value ‘1’), the engine is controlled using the target fuel injection amount obtained from the correction of the basic fuel injection amount toward the increase direction, in the case that the engine is operated together with the recirculation of the exhaust in the whole range that the engine is operable together with the recirculation of the exhaust.

7 Claims, 5 Drawing Sheets



U.S. PATENT DOCUMENTS

2008/0256929 A1 * 10/2008 Sugimoto 60/278

FOREIGN PATENT DOCUMENTS

JP 2001-164999 A 6/2001
JP 2001-349231 A 12/2001
JP 2002-4901 A 1/2002
JP 2004-353580 A 12/2004
JP 2008-267261 A 11/2008

* cited by examiner

Fig. 1

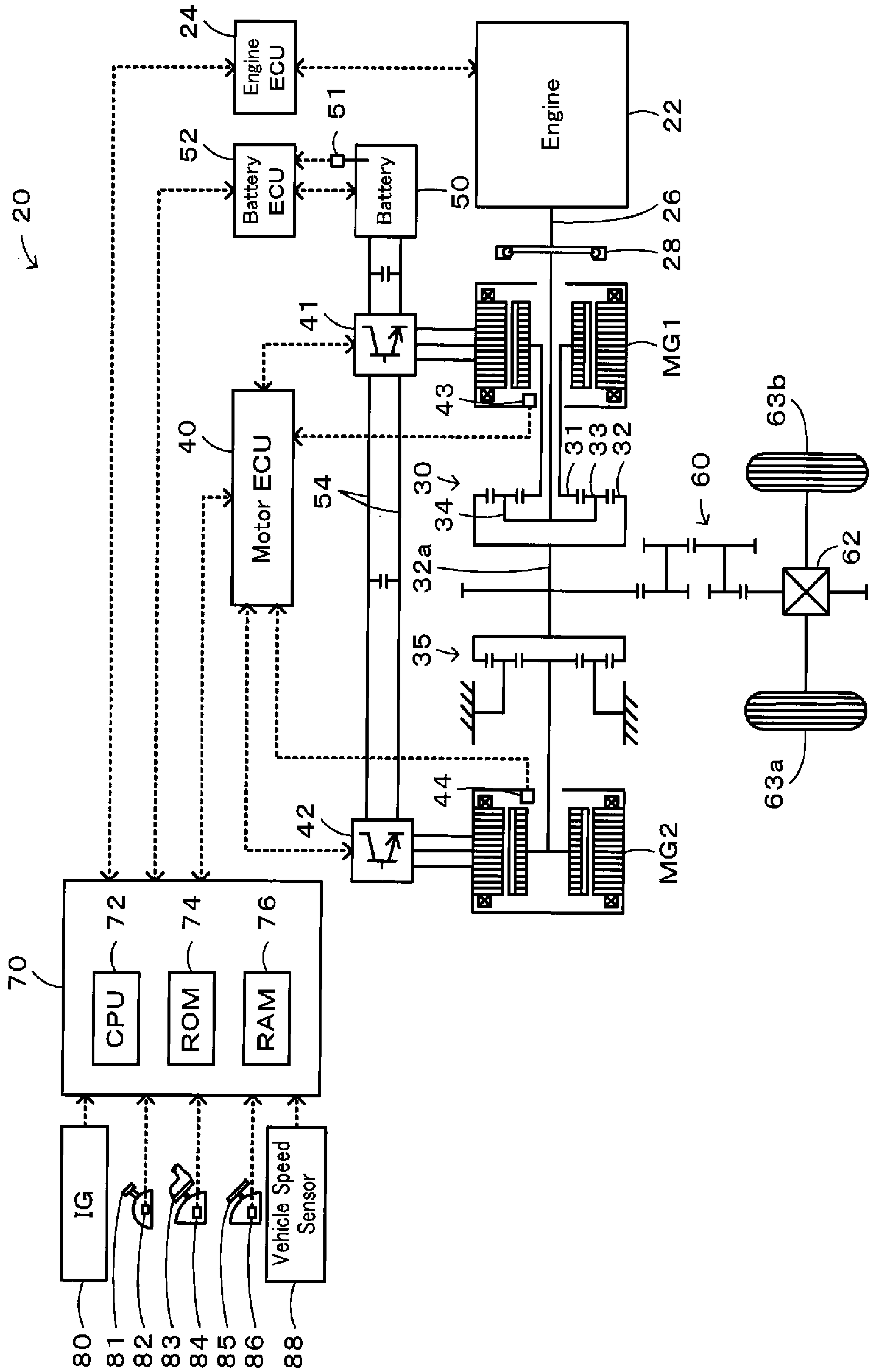

20
24
Engine ECU
22
Engine
52
Battery ECU
51
50
Battery
26
28
41
40
Motor ECU
43
MG1
54
30
34
31
33
32
32a
60
62
63a
63b
35
44
42
MG2
70
72
CPU
74
ROM
76
RAM
IG
Vehicle Speed Sensor
80
81
82
83
84
85
86
88

Fig. 2

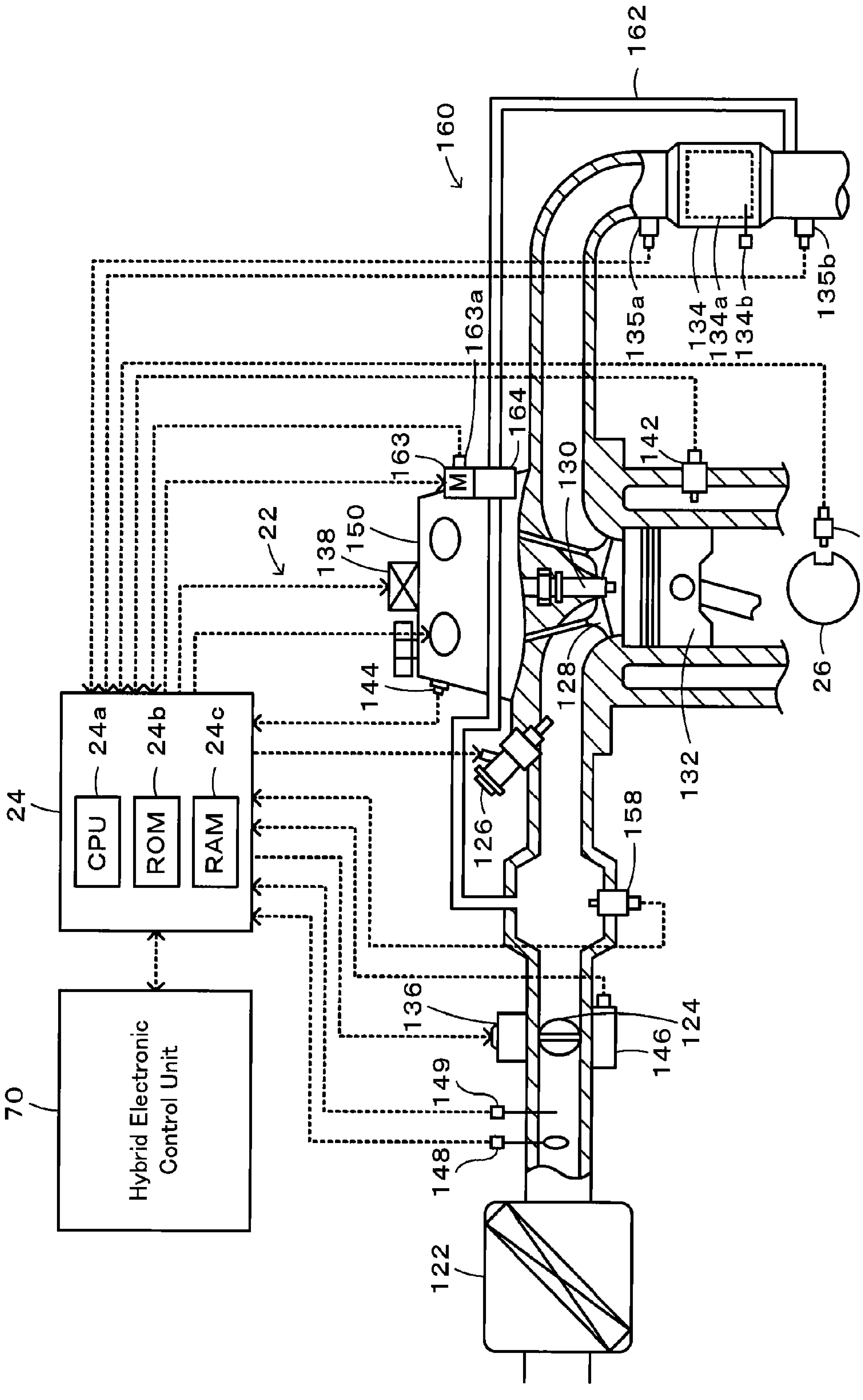

24
CPU
ROM
RAM
24a
24b
24c
70
Hybrid Electronic Control Unit
22
26
122
124
126
128
130
132
134
134a
134b
135a
135b
136
138
140
142
144
146
148
149
150
158
160
162
163
163a
164
M

Fig. 3

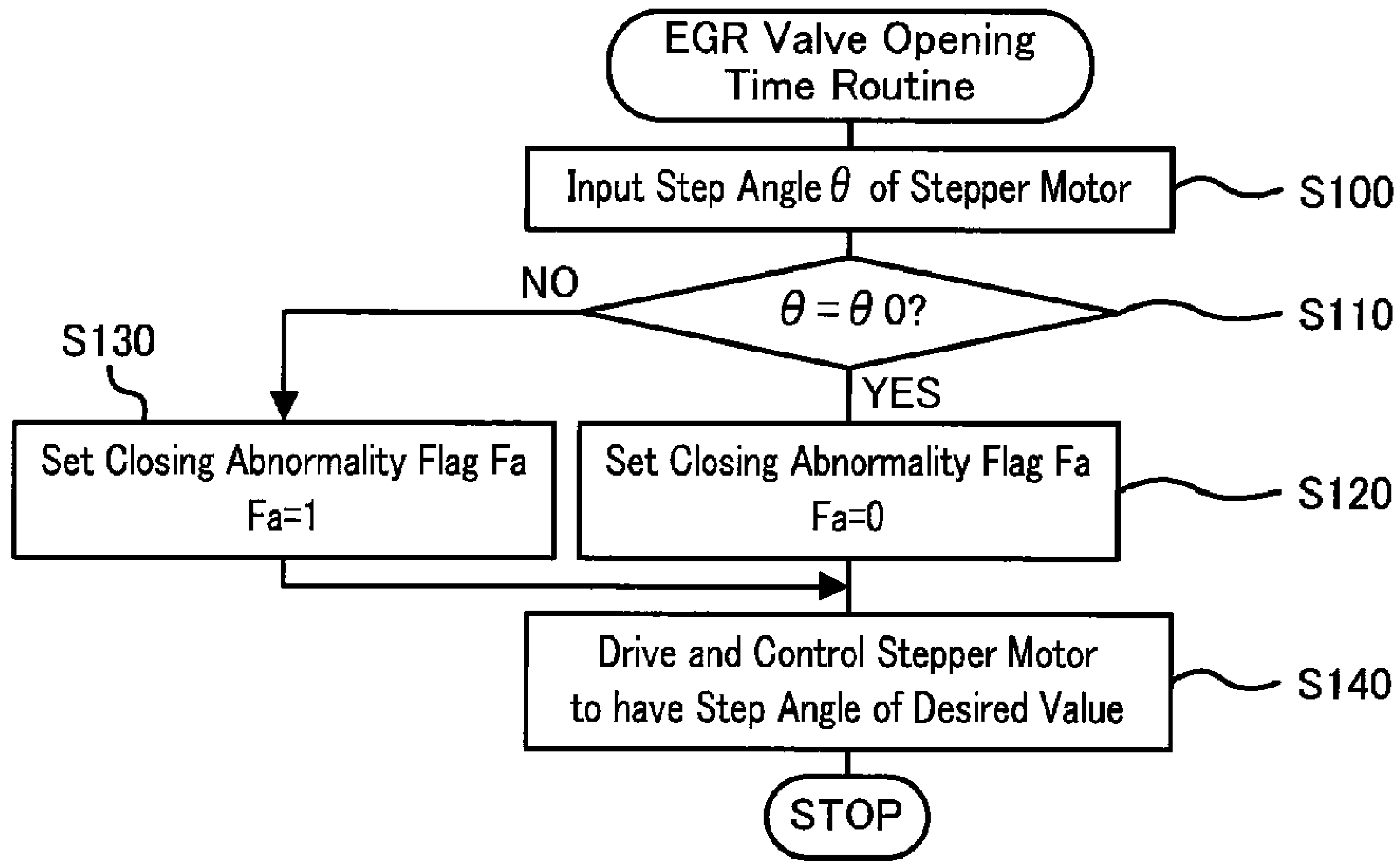

EGR Valve Opening Time Routine
Input Step Angle θ of Stepper Motor
S100
θ = θ 0?
S110
NO
YES
S130
Set Closing Abnormality Flag Fa Fa=1
Set Closing Abnormality Flag Fa Fa=0
S120
Drive and Control Stepper Motor to have Step Angle of Desired Value
S140
STOP

Fig. 4

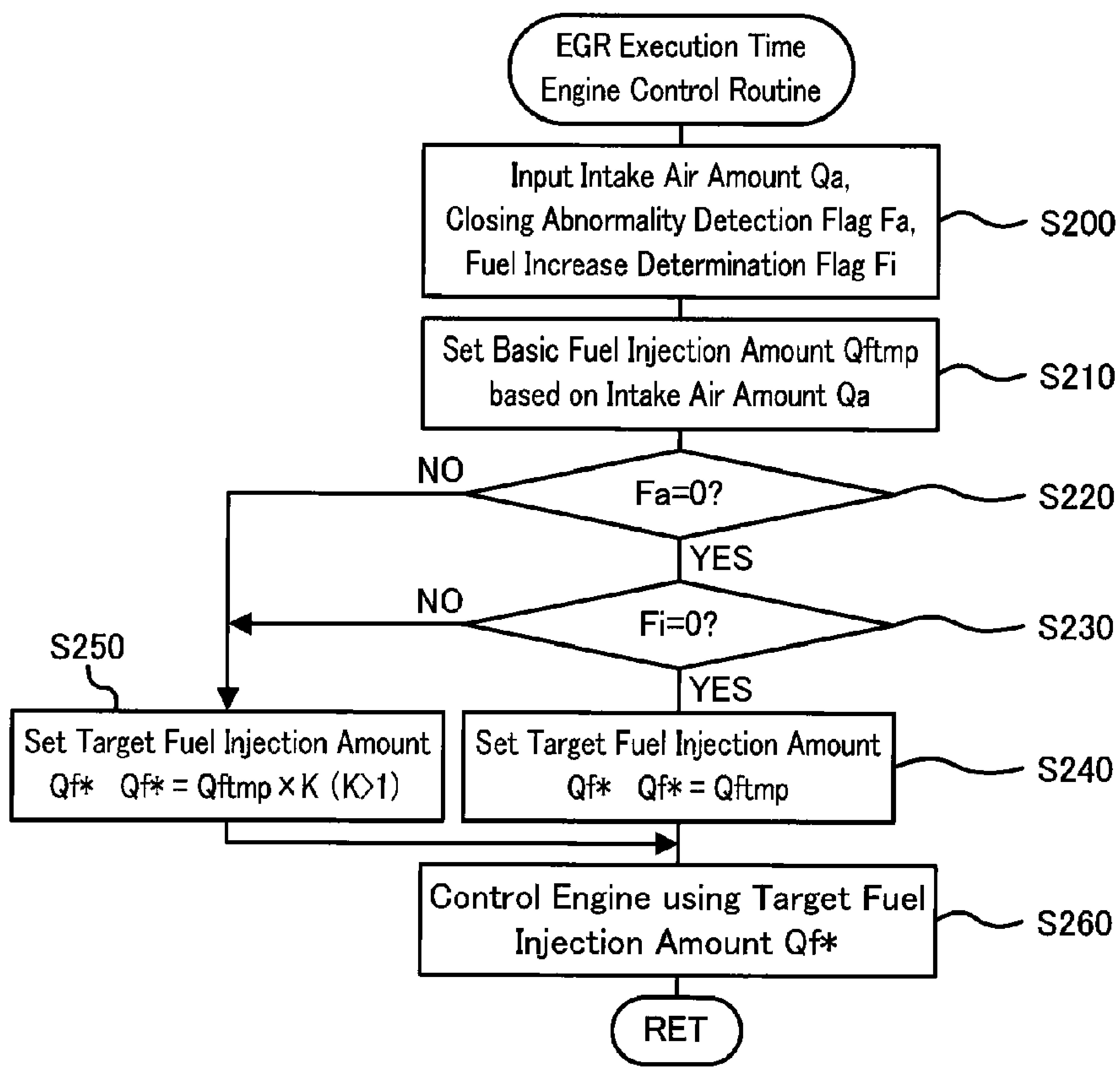

EGR Execution Time Engine Control Routine
Input Intake Air Amount Qa, Closing Abnormality Detection Flag Fa, Fuel Increase Determination Flag Fi
S200
Set Basic Fuel Injection Amount Qftmp based on Intake Air Amount Qa
S210
Fa=0?
S220
NO
YES
Fi=0?
S230
NO
YES
S250
Set Target Fuel Injection Amount Qf* Qf* = Qftmp × K (K>1)
Set Target Fuel Injection Amount Qf* Qf* = Qftmp
S240
Control Engine using Target Fuel Injection Amount Qf*
S260
RET

Fig. 5

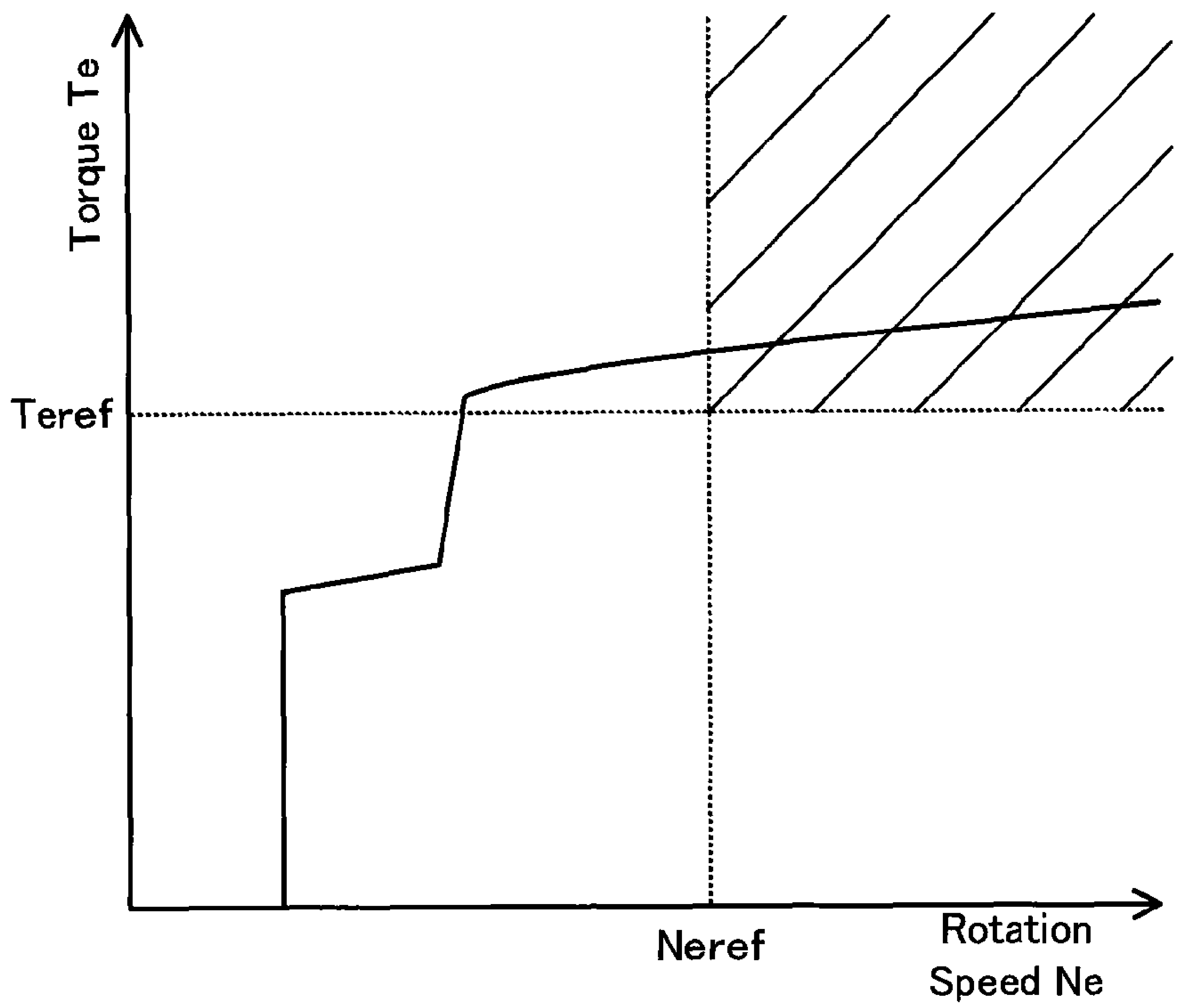

Torque Te
Teref
Neref
Rotation Speed Ne

Fig. 6

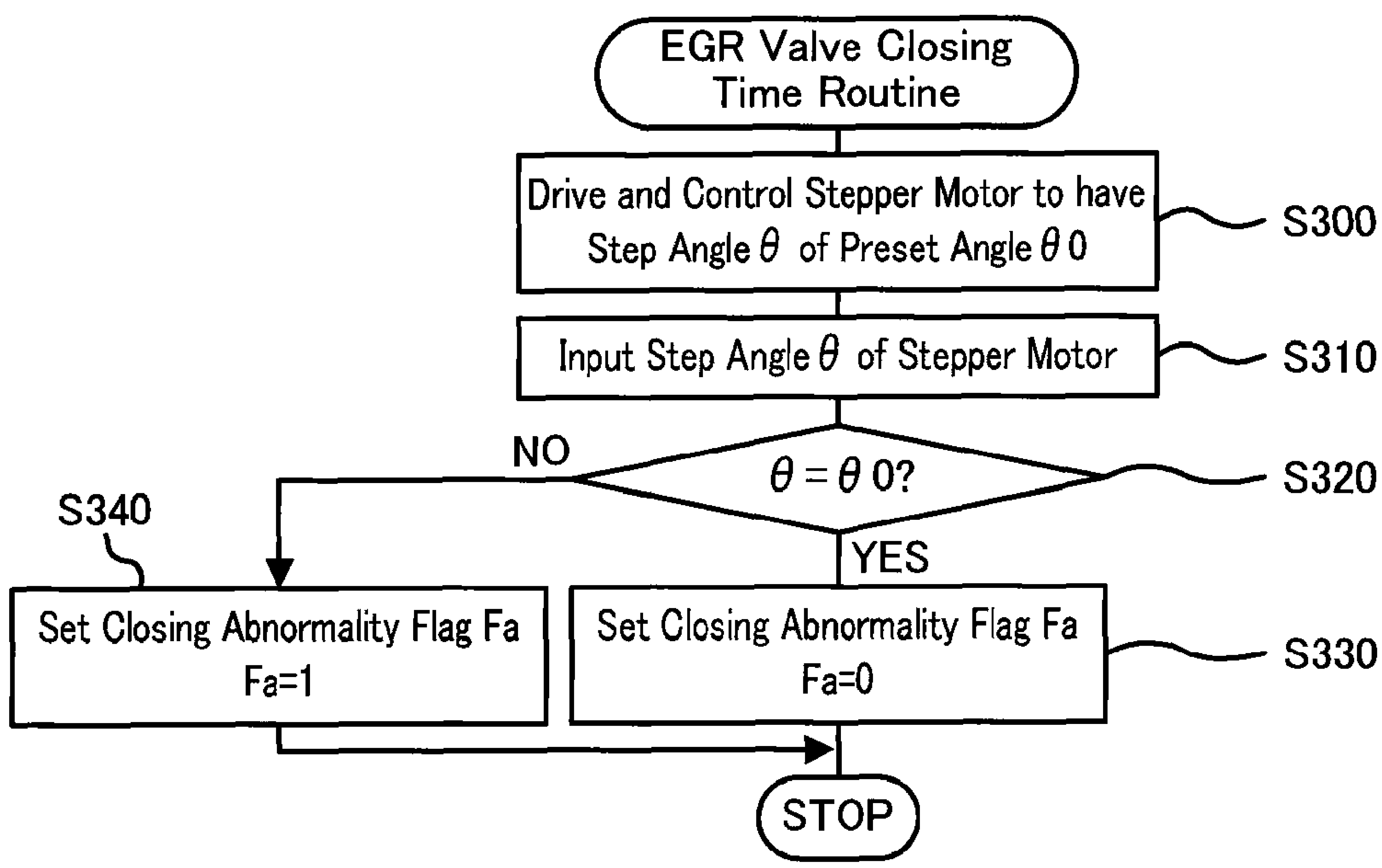
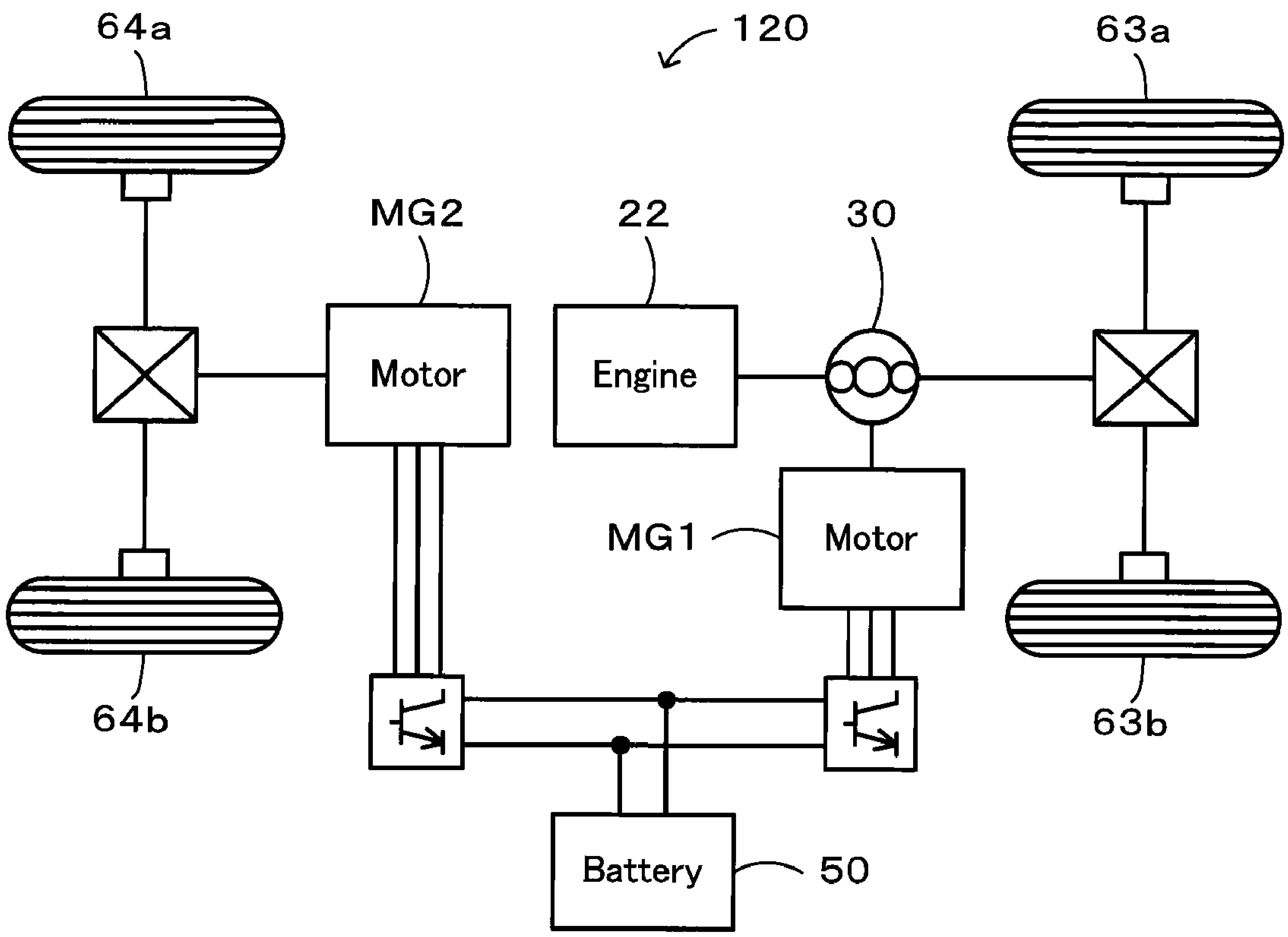

EGR Valve Closing Time Routine
Drive and Control Stepper Motor to have Step Angle θ of Preset Angle θ0
S300
Input Step Angle θ of Stepper Motor
S310
θ = θ0?
S320
NO
YES
S340
Set Closing Abnormality Flag Fa Fa=1
Set Closing Abnormality Flag Fa Fa=0
S330
STOP

Fig. 7


64a
120
63a
MG2
22
30
Motor
Engine
MG1
Motor
64b
63b
Battery
50

INTERNAL COMBUSTION ENGINE SYSTEM, CONTROL METHOD THEREOF, AND VEHICLE

This is a 371 national phase application of PCT/JP2009/050539 filed 16 Jan. 2009, claiming priority to Japanese Patent Application No. JP 2008-153302 filed 11 Jun. 2008, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to an internal combustion engine system and a control method thereof. More specifically, the invention pertains to an internal combustion engine system having an internal combustion engine, an exhaust gas recirculation unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a driver that drives the exhaust regulating valve to be open and close, and an exhaust purification unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine, and a control method of the internal combustion engine system.

BACKGROUND ART

In one proposed internal combustion engine system, the fuel supply amount is corrected to be larger against the smaller differential pressure between the pressure in an air intake conduit while opening an exhaust recirculation valve and the pressure in the air intake conduit while closing the exhaust recirculation valve (see, for example, Patent Document 1). In this system, it is determined that the degree of clogging in an exhaust gas recirculation conduit or the exhaust gas recirculation valve becomes more against the smaller differential pressure between the pressure in the air intake conduit while opening the exhaust recirculation valve and the pressure in the air intake conduit while closing the exhaust recirculation valve, and determined that the air-fuel ratio is increased. In this system, the fuel supply amount is corrected to be larger and emissions of nitrogen oxides (NOx) are reduced.

Patent Document 1: Japanese Patent Laid-Open No. 2001-349231

DISCLOSURE OF THE INVENTION

In internal combustion engine systems having such an exhaust gas recirculation device, when the internal combustion engine is operated together with the recirculation of exhaust gas at an operation point of a relatively high torque, a fuel increase correction is performed to prevent that the catalyst of an exhaust purification device attached to the exhaust system of the internal combustion engine is overheated. In the case that it is disabled to determine the degree of opening of the exhaust recirculation valve due to foreign matter such as soot adhering to the exhaust recirculation valve, lack of the recirculation amount occurs and there happens a case that the catalyst is unexpectedly overheated, resulting that the exhaust emission is worsened.

In the internal combustion engine system and a control method of the internal combustion engine system of the invention, the main object of the invention is to prevent that a catalyst of an exhaust purifying unit is overheated regardless of occurrence of a closing abnormality that an exhaust regulating valve does not become in a totally closed state.

In order to attain the main object, the internal combustion engine system and the control method of the internal combustion engine system of the invention have the configurations discussed below.

According to one aspect, the present invention is directed to an internal combustion engine system. The internal combustion engine system, having an internal combustion engine, an exhaust gas recirculation unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a valve driver that drives the exhaust regulating valve to be open and close, and an exhaust purification unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine, the internal combustion engine system has: a closing abnormality detection module that detects a closing abnormality that the exhaust regulating valve does not become in a totally closed state; and a control module that controls the internal combustion engine, upon no detection of the closing abnormality by the closing abnormality detection module, so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque, upon detection of the closing abnormality by the closing abnormality detection module, the control module controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range.

The internal combustion engine system according to this aspect of the invention, upon no detection of a closing abnormality that the exhaust regulating valve does not become in a totally closed state, controls the internal combustion engine so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque, upon detection of the closing abnormality controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range. This arrangement effectively prevents that the catalyst is unexpectedly overheated even when lack of the recirculation amount occurs. It is thus prevented that the exhaust emission is worsened.

In one preferable application of the internal combustion engine system of the invention, the valve driver may be a stepper motor, and the closing abnormality detection module may detect the closing abnormality when a step angle of the stepper motor is not a step angle corresponding to the totally closed state of the exhaust regulating valve regardless of an instruction to totally close the exhaust regulating valve, or when the step angle of the stepper motor is not opened more from the step angle corresponding to the totally closed state of the exhaust regulating valve regardless of an instruction to open the exhaust regulating valve from the totally closed state. This arrangement enables to detect the closing abnormality more adequately based on the step angle of the stepper motor.

In another preferable application of the internal combustion engine system of the invention, the preset range may be a whole range that the internal combustion engine is operable while the internal combustion engine is operated together with the recirculation of the exhaust. This arrangement more certainly prevents unexpected overheating of the catalyst.

According to another aspect, the present invention is directed to a vehicle equipped with any of the above arrangements of the internal combustion engine system, the vehicle being driven with power from the internal combustion engine. Here the internal combustion engine system having an internal combustion engine, an exhaust gas recirculation unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a valve driver that drives the exhaust regulating valve to be open and close, and an exhaust purification unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine, fundamentally has: a closing abnormality detection module that detects a closing abnormality that the exhaust regulating valve does not become in a totally closed state; and a control module that controls the internal combustion engine, upon no detection of the closing abnormality by the closing abnormality detection module, so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque, upon detection of the closing abnormality by the closing abnormality detection module, the control module controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range.

The vehicle according to this aspect of the invention has any of the above arrangements of the internal combustion engine system. The vehicle thus has at least part of effects that the internal combustion engine system of the invention has such as an effect of effectively preventing that the catalyst is unexpectedly overheated regardless of when lack of the recirculation amount occurs.

According to still another aspect, the present invention is directed to a control method of an internal combustion engine system having an internal combustion engine, an exhaust gas recirculation unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a valve driver that drives the exhaust regulating valve to be open and close, and an exhaust purification unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine. The control method of the internal combustion engine system includes: upon no occurrence of a closing abnormality that the exhaust regulating valve does not become in a totally closed state, controlling the internal combustion engine so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque, upon occurrence of the closing abnormality controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range.

The control method of the internal combustion engine system according to this aspect of the invention, upon no detection of a closing abnormality that the exhaust regulating valve does not become in a totally closed state, controls the internal combustion engine so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque, upon detection of the closing abnormality controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range. This arrangement effectively prevents that the catalyst is unexpectedly overheated even when lack of the recirculation amount occurs. It is thus prevented that the exhaust emission is worsened.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically illustrates the configuration of a hybrid vehicle **20** in one embodiment of the invention;

FIG. **2** is a schematic view showing the structure of an engine **22**;

FIG. **3** is a flowchart showing an EGR valve opening time routine executed by an engine ECU **24** in the embodiment;

FIG. **4** is a flowchart showing an EGR execution time engine control routine executed by the engine ECU **24** in the embodiment;

FIG. **5** shows one example of a high-load operation range where a purifying catalyst **134***a* has a possibility to be overheated;

FIG. **6** is a flowchart showing an EGR valve closing time routine executed by the engine ECU **24** in the embodiment; and

FIG. **7** schematically illustrates the configuration of another hybrid vehicle **120** in one modified example.

BEST MODES OF CARRYING OUT THE INVENTION

One mode of carrying out the invention is discussed below as a preferred embodiment. FIG. **1** schematically illustrates the configuration of a hybrid vehicle **20** equipped with an internal combustion engine system in one embodiment according to the invention. As illustrated, the hybrid vehicle **20** of the embodiment includes the engine **22**, a three shaft-type power distribution integration mechanism **30** connected via a damper **28** to a crankshaft **26** or an output shaft of the engine **22**, a motor MG**1** connected to the power distribution integration mechanism **30** and designed to have power generation capability, a reduction gear **35** attached to a ring gear shaft **32***a* or a driveshaft linked with the power distribution integration mechanism **30**, a motor MG**2** connected to the reduction gear **35**, and a hybrid electronic control unit **70** configured to control the operations of the whole hybrid vehicle **20**.

The engine **22** is an internal combustion engine that consumes a hydrocarbon fuel, such as gasoline or light oil, to output power. As shown in FIG. **2**, the air cleaned by an air cleaner **122** and taken into an air intake conduit via a throttle valve **124** is mixed with the atomized fuel injected from a fuel injection valve **126** to the air-fuel mixture. The air-fuel mixture is introduced into a combustion chamber by means of an intake valve **128**. The introduced air-fuel mixture is ignited with spark made by a spark plug **130** to be explosively combusted. The reciprocating motions of a piston **132** pressed down by the combustion energy are converted into rotational motions of the crankshaft **26**. The exhaust from the engine **22** goes through a catalytic converter **134** having a purifying catalyst (three-way catalyst) **134***a* to convert toxic components included in the exhaust, that is, carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx), into harmless components, and is discharged to the outside air or supplied to an air intake system via an EGR (Exhaust Gas Recirculation) system **160**. The EGR system **160** has an EGR pipe **162** connected downstream of the catalytic converter **134** to supply the exhaust into a surge tank of the air intake system, and an EGR valve **164** located at the EGR pipe **162** and driven by a stepper motor **163**. The EGR system **160** is constructed to supply the exhaust as the uncombusted gas to the air intake system controlling the supply amount by regulating the opening degree of the EGR valve **164**. In the structure of the engine **22**, the intake air mixed with the exhaust is further mixed with the atomized fuel to the air-fuel mixture, which is introduced into the combustion chamber.

The engine **22** is under control of an engine electronic control unit (hereafter referred to as engine ECU) **24**. The engine ECU **24** is constructed as a microprocessor including a CPU **24***a*, a ROM **24***b* configured to store processing programs, a RAM **24***c* configured to temporarily store data, input and output ports (not shown), and a communication port (not shown). The engine ECU **24** receives, via its input port, signals from various sensors designed to measure and detect the operating conditions of the engine **22**. The signals input into the engine ECU **24** include a crank position from a crank position sensor **140** detected as the rotational position of the crankshaft **26**, a cooling water temperature Tw from a water temperature sensor **142** measured as the temperature of cooling water in the engine **22**, an in-cylinder pressure from a non-illustrated pressure sensor located inside the combustion chamber, cam positions from a cam position sensor **144** detected as the rotational positions of camshafts driven to open and close the intake valve **128** and an exhaust valve for gas intake and exhaust into and from the combustion chamber, a throttle position from a throttle valve position sensor **146** detected as the position of the throttle valve **124**, an intake air amount Qa from an air flow meter **148** located in the air intake conduit measured as a rate of mass flow of the intake air, an intake air temperature from a temperature sensor **149** located in the air intake conduit, an intake air pressure from an intake air pressure sensor **158** detected as the pressure inside the air intake conduit, an air-fuel ratio from the air-fuel ratio sensor **135***a*, an oxygen signal from the oxygen sensor **135***b*, a catalyst temperature from a temperature sensor **134***b* measured as the temperature of the purifying catalyst **134***a*, and a step angle θ from a step angle sensor **163***a* detected as a step angle of the stepper motor **163**. The engine ECU **24** outputs, via its output port, diverse control signals and driving signals to drive and control the engine **22**. The signals output from the engine ECU **24** include driving signals to the fuel injection valve **126**, driving signals to a throttle valve motor **136** driven to regulate the position of the throttle valve **124**, control signals to an ignition coil **138** integrated with an igniter, control signals to a variable valve timing mechanism **150** to vary the open and close timings of the intake valve **128**, and driving signals to the stepper motor **163** driven to regulate the opening degree of the EGR valve **164**. The engine ECU **24** establishes communication with the hybrid electronic control unit **70** to drive and control the engine **22** in response to control signals received from the hybrid electronic control unit **70** and to output data regarding the operating conditions of the engine **22** to the hybrid electronic control unit **70** according to the requirements. The engine ECU **24** also performs several arithmetic operations to compute a rotation speed of the crankshaft **26** or a rotation speed Ne of the engine **22** from the crank position input from the crank position sensor **140**.

The power distribution integration mechanism **30** has a sun gear **31** that is an external gear, a ring gear **32** that is an internal gear and is arranged concentrically with the sun gear **31**, multiple pinion gears **33** that engage with the sun gear **31** and with the ring gear **32**, and a carrier **34** that holds the multiple pinion gears **33** in such a manner as to allow free revolution thereof and free rotation thereof on the respective axes. Namely the power distribution integration mechanism **30** is constructed as a planetary gear mechanism that allows for differential motions of the sun gear **31**, the ring gear **32**, and the carrier **34** as rotational elements. The carrier **34**, the sun gear **31**, and the ring gear **32** in the power distribution integration mechanism **30** are respectively coupled with the crankshaft **26** of the engine **22**, the motor MG**1**, and the reduction gear **35** via ring gear shaft **32***a*. While the motor MG**1** functions as a generator, the power output from the engine **22** and input through the carrier **34** is distributed into the sun gear **31** and the ring gear **32** according to the gear ratio. While the motor MG**1** functions as a motor, on the other hand, the power output from the engine **22** and input through the carrier **34** is combined with the power output from the motor MG**1** and input through the sun gear **31** and the composite power is output to the ring gear **32**. The power output to the ring gear **32** is thus finally transmitted to the driving wheels **63***a* and **63***b* via the gear mechanism **60**, and the differential gear **62** from ring gear shaft **32***a*.

Both the motors MG**1** and MG**2** are known synchronous motor generators that are driven as a generator and as a motor. The motors MG**1** and MG**2** transmit electric power to and from a battery **50** via inverters **41** and **42**. Power lines **54** that connect the inverters **41** and **42** with the battery **50** are constructed as a positive electrode bus line and a negative electrode bus line shared by the inverters **41** and **42**. This arrangement enables the electric power generated by one of the motors MG**1** and MG**2** to be consumed by the other motor. The battery **50** is charged with a surplus of the electric power generated by the motor MG**1** or MG**2** and is discharged to supplement an insufficiency of the electric power. When the power balance is attained between the motors MG**1** and MG**2**, the battery **50** is neither charged nor discharged. Operations of both the motors MG**1** and MG**2** are controlled by a motor electronic control unit (hereafter referred to as motor ECU) **40**. The motor ECU **40** receives diverse signals required for controlling the operations of the motors MG**1** and MG**2**, for example, signals from rotational position detection sensors **43** and **44** that detect the rotational positions of rotors in the motors MG**1** and MG**2** and phase currents applied to the motors MG**1** and MG**2** and measured by current sensors (not shown). The motor ECU **40** outputs switching control signals to the inverters **41** and **42**. The motor ECU **40** communicates with the hybrid electronic control unit **70** to control operations of the motors MG**1** and MG**2** in response to control signals transmitted from the hybrid electronic control unit **70** while outputting data relating to the operating conditions of the motors MG**1** and MG**2** to the hybrid electronic control unit **70** according to the requirements. The motor ECU **40** also performs arithmetic operations to compute rotation speeds Nm**1** and Nm**2** of the motors MG**1** and MG**2** from the output signals of the rotational position detection sensors **43** and **44**.

The battery **50** is under control of a battery electronic control unit (hereafter referred to as battery ECU) **52**. The battery ECU **52** receives diverse signals required for control of the battery **50**, for example, an inter-terminal voltage measured by a voltage sensor (not shown) disposed between terminals of the battery **50**, a charge-discharge current measured by a current sensor (not shown) attached to the power line **54** connected with the output terminal of the battery **50**, and a battery temperature Tb measured by a temperature sensor **51** attached to the battery **50**. The battery ECU **52** outputs data relating to the state of the battery **50** to the hybrid electronic control unit **70** via communication according to the requirements. The battery ECU **52** also performs various arithmetic operations for management and control of the battery **50**. A remaining charge or state of charge (SOC) of the battery **50** is calculated from an integrated value of the charge-discharge current measured by the current sensor. An input limit Win as a maximum allowable charging electric power to be charged in the battery **50** and an output limit Wout as a maximum allowable discharging electric power to be discharged from the battery **50** are set corresponding to the calculated state of charge (SOC) and the battery temperature Tb. A concrete procedure of setting the input and output limits Win and Wout of the battery **50** sets base values of the input limit Win and the output limit Wout corresponding to the battery temperature Tb, specifies an input limit correction factor and an output limit correction factor corresponding to the state of charge (SOC) of the battery **50**, and multiplies the base values of the input limit Win and the output limit Wout by the specified input limit correction factor and output limit correction factor to determine the input limit Win and the output limit Wout of the battery **50**.

The hybrid electronic control unit **70** is constructed as a microprocessor including a CPU **72**, a ROM **74** that stores processing programs, a RAM **76** that temporarily stores data, and a non-illustrated input-output port, and a non-illustrated communication port. The hybrid electronic control unit **70** receives various inputs via the input port: an ignition signal from an ignition switch **80**, a gearshift position SP from a gearshift position sensor **82** that detects the current position of a gearshift lever **81**, an accelerator opening Acc from an accelerator pedal position sensor **84** that measures a step-on amount of an accelerator pedal **83**, a brake pedal position BP from a brake pedal position sensor **86** that measures a step-on amount of a brake pedal **85**, and a vehicle speed V from a vehicle speed sensor **88**. The hybrid electronic control unit **70** communicates with the engine ECU **24**, the motor ECU **40**, and the battery ECU **52** via the communication port to transmit diverse control signals and data to and from the engine ECU **24**, the motor ECU **40**, and the battery ECU **52**, as mentioned previously. In the hybrid vehicle **20** of the embodiment, the gearshift position sensor **82** detects one of several gearshift positions such as a parking position (P position), a neutral position (N position), a drive position (D position), and a reverse position (R position) as the gearshift position SP.

The hybrid vehicle **20** of the embodiment thus constructed calculates a torque demand to be output to the ring gear shaft **32***a* functioning as the drive shaft, based on observed values of a vehicle speed V and an accelerator opening Acc, which corresponds to a driver's step-on amount of the accelerator pedal **83**. The engine **22** and the motors MG**1** and MG**2** are subjected to operation control to output a required level of power corresponding to the calculated torque demand to the ring gear shaft **32***a*. The operation control of the engine **22** and the motors MG**1** and MG**2** selectively effectuates one of a torque conversion drive mode, a charge-discharge drive mode, and a motor drive mode. The torque conversion drive mode controls the operations of the engine **22** to output a quantity of power equivalent to the required level of power, while driving and controlling the motors MG**1** and MG**2** to cause all the power output from the engine **22** to be subjected to torque conversion by means of the power distribution integration mechanism **30** and the motors MG**1** and MG**2** and output to the ring gear shaft **32***a*. The charge-discharge drive mode controls the operations of the engine **22** to output a quantity of power equivalent to the sum of the required level of power and a quantity of electric power consumed by charging the battery **50** or supplied by discharging the battery **50**, while driving and controlling the motors MG**1** and MG**2** to cause all or part of the power output from the engine **22** equivalent to the required level of power to be subjected to torque conversion by means of the power distribution integration mechanism **30** and the motors MG**1** and MG**2** and output to the ring gear shaft **32***a*, simultaneously with charge or discharge of the battery **50**. The motor drive mode stops the operations of the engine **22** and drives and controls the motor MG**2** to output a quantity of power equivalent to the required level of power to the ring gear shaft **32***a*. Both of the torque conversion drive mode and the charge-discharge drive mode are modes for controlling the engine **22** and the motors MG**1** and MG**2** to output the required level of power to the ring gear shaft **32***a* with operation of the engine **22** and the control in the both modes practically has no difference. A combination of the both modes is thus referred to as an engine load operation mode hereafter.

The description regards the operations of the internal combustion engine system installed in the hybrid vehicle **20** of the embodiment having the configuration discussed above. The combination of the engine **22**, the catalytic converter **134**, the EGR system **160**, and the engine ECU **24** primarily corresponds to the internal combustion engine system in the embodiment. FIG. **3** is a flowchart showing an EGR valve opening time routine executed by the engine ECU **24**. This routine is executed when it is instructed by the hybrid electronic control unit **70** to open the EGR valve **164** from its totally closed state.

In the EGR valve opening time routine, the CPU **24***a* of the engine ECU **24** inputs the step angle θ of the stepper motor **163** from the step angle sensor **163***a* (step S**100**), and determines whether the input step angle θ is equal to a preset angle θ0 that corresponds to the totally closed state of the EGR valve **164** (step S**110**). There is a case that an closing abnormality where the EGR valve **164** does not become in the totally closed state occurs when foreign matter such as soot adheres to the EGR valve **164**. The processing of step S**110** is the processing to detect this closing abnormality when the step angle θ is not equal to the preset angle θ0. When the step angle θ of the stepper motor **163** is equal to the preset angle θ0 (the EGR valve **164** is in the totally closed state), the CPU **24***a* sets an closing abnormality detection flag Fa to value '0' (step S**120**). The closing abnormality detection flag Fa is set to value '0' when the closing abnormality is not detected and set to value '1' when the closing abnormality is detected. The CPU **24***a* then drives and controls the stepper motor **163** so that the step angle of the stepper motor **163** (the opening degree of the EGR valve **164**) becomes a desired value (for example, a value set based on the intake air amount Qa and the rotation speed Ne of the engine **22**) (step S**140**), and terminates the EGR valve opening time routine. When the step angle θ of the stepper motor **163** is not equal to the preset angle θ0 (the EGR valve **164** is not in the totally closed state) in the processing of step S**110**, the CPU **24***a* sets the closing abnormality detection flag Fa to value '1' (step S**130**). The CPU **24***a* then drives and controls the stepper motor **163** so that the step angle of the stepper motor **163** (the opening degree of the EGR valve **164**) becomes the desired value (step S**140**), and terminates the EGR valve opening time routine.

Next, control of the engine **22** during execution of the EGR is explained. FIG. **4** is a flowchart showing an EGR execution time engine control routine executed by the engine ECU **24**. This routine is executed repeatedly at preset time intervals (for example, at every several msec) under satisfaction of an EGR execution condition. In the embodiment, the EGR execution condition is satisfied when the cooling water temperature Tw from the water temperature sensor **142** is more than or equal to a preset temperature indicating the warm-up completion (for example, 65° C. or 70° C.) and the both of the rotation speed Ne and the intake air amount Qa of the engine **22** are within a preset range where the EGR execution is required (for example, within a range where the EGR execution is required to enhance fuel efficiency and defined by rotation speeds less than a threshold value of the rotation speed Ne and intake air amounts less than a threshold value of the intake air amount Qa, or within a range where the EGR execution is required to prevent overheating of the purifying catalyst **134***a* and defined by rotation speeds more than or equal to a threshold value of the rotation speed Ne or intake air amounts more than or equal to a threshold value of the intake air amount Qa).

In the EGR execution time engine control routine, the CPU **24***a* of the engine ECU **24** inputs the intake air amount Qa from the flow meter **148**, the closing abnormality detection flag Fa, and a fuel increase determination flag Fi (step S**200**). The closing abnormality detection flag Fa is read and input from a preset address of the RAM **24***c* storing the setting to value '0' when the closing abnormality where the EGR valve **164** does not become in the totally closed state is not detected and to value '1' when the closing abnormality is detected in the EGR valve opening time routine of FIG. **3**. The fuel increase determination flag Fi is read and input from a preset address of the RAM **24***c* storing the setting to value '0' when the engine **22** is not operated in a preset high-load operation range where the purifying catalyst **134***a* has a possibility to be overheated and to value '1' when the engine **22** is operated in the preset high-load operation range where the purifying catalyst **134***a* has a possibility to be overheated. FIG. **5** shows one example of the high-load operation range where the purifying catalyst **134***a* has a possibility to be overheated. In the embodiment, when the engine **22** is operated in the range shown as a diagonally shaded area in the figure and defined by the rotation sped Ne more than or equal to the threshold valve Neref and the output torque Te more than or equal to the threshold value Teref, it is determined that there is a possibility that the purifying catalyst **134***a* is overheated and the fuel increase determination flag Fi is set to value '1'.

After the data input, the CPU **24***a* sets a basic fuel injection amount Qftmp which makes a target air-fuel ratio (for example, a stoichiometric air-fuel ratio) according to the input intake air amount Qa (step S**210**). The CPU **24***a* subsequently determines whether the closing abnormality detection flag Fa is equal to value '0' or not (step S**220**). When the closing abnormality detection flag Fa is equal to value '0', that is, when the closing abnormality where the EGR valve **164** does not become in the totally closed state, the CPU **24***a* determines whether the fuel increase determination flag Fi is equal to value '0' or not (step S**230**). When the fuel increase determination flag Fi is equal to value '0', the CPU **24***a* sets the basic fuel injection amount Qftmp as a target fuel injection amount Qf* (step S**240**). When the fuel increase determination flag Fi is equal to value '1', the CPU **24***a* sets the product of the basic fuel injection amount Qftmp and a correction factor K larger than value '1' (Qftmp·K) as the target fuel injection amount Qf* (step S**250**). The CPU **24***a* then controls the engine **22** using the set target fuel injection amount Qf* (step S**260**), and terminates the EGR execution time engine control routine. In the engine **22**, required control including fuel injection control using the target fuel injection amount Qf*, intake air amount control, ignition control, and open-close timing control of the intake valve **128** is performed. Overheating of the purifying catalyst **134***a* occurs with a higher possibility when the fuel increase determination flag Fi is equal to value '1' that is to say the engine **22** is operated in the preset high-load operation range. The engine **22** is controlled using the target fuel injection amount Qf* obtained from the correction of the basic fuel injection amount Qftmp toward the increase direction, and a ratio of the atomized fuel in the air-fuel mixture of the intake air, the exhaust, and the atomized fuel is increased to lower the combustion temperature of the air-fuel mixture. This enables to prevent the overheating of the purifying catalyst **134***a*.

When the closing abnormality detection flag Fa is equal to value '1' in the processing of step S**220**, the CPU **24***a* sets the product of the basic fuel injection amount Qftmp and the above correction factor K (Qftmp·K) as the target fuel injection amount Qf* (step S**250**). The CPU **24***a* controls the engine **22** using the set target fuel injection amount Qf* (step S**260**), and terminates the EGR execution time engine control routine. As described, the engine **22** is controlled, using the target fuel injection amount Qf* obtained from the correction of the basic fuel injection amount Qftmp toward the increase direction, in the whole range that the engine **22** is operable together with the recirculation of the exhaust. The ratio of the atomized fuel in the air-fuel mixture of the intake air, the exhaust, and the atomized fuel is increased to lower the combustion temperature of the air-fuel mixture, and it is enabled to prevent the overheating of the purifying catalyst **134***a*. Accordingly, it is prevented that the purifying catalyst **134***a* is unexpectedly overheated even when foreign matter such as soot adheres to the EGR valve **164** and lack of the recirculation amount of the exhaust occurs. It is thus effectively prevented that the exhaust emission is worsened.

In the hybrid vehicle **20** of the embodiment described above, upon no detection of the closing abnormality where the EGR valve **164** does not become in the totally closed state, the engine **22** is controlled using the target fuel injection amount Qf* obtained from the correction of the basic fuel injection amount Qftmp toward the increase direction, in the case that the engine **22** is operated together with the recirculation of the exhaust in the preset high-load operation range. Upon detection of the closing abnormality where the EGR valve **164** does not become in the totally closed state, the engine **22** is controlled using the target fuel injection amount Qf* obtained from the correction of the basic fuel injection amount Qftmp toward the increase direction, in the case that the engine **22** is operated together with the recirculation of the exhaust in the whole range that the engine **22** is operable together with the recirculation of the exhaust. Accordingly, it is prevented that the purifying catalyst **134***a* is unexpectedly overheated even when foreign matter such as soot adheres to the EGR valve **164** and lack of the recirculation amount of the exhaust occurs. It is thus effectively prevented that the exhaust emission is worsened.

In the hybrid vehicle **20** of the embodiment, upon detection of the closing abnormality where the EGR valve **164** does not become in the totally closed state, the engine **22** is controlled using the target fuel injection amount Qf* obtained from the correction of the basic fuel injection amount Qftmp toward the increase direction, in the case that the engine **22** is operated together with the recirculation of the exhaust in the whole range that the engine **22** is operable together with the recirculation of the exhaust. This is not essential. Upon detection of the closing abnormality, any other arrangement may be applicable such as an arrangement of controlling the engine **22** using the target fuel injection amount Qf* obtained from the correction of the basic fuel injection amount Qftmp toward the increase direction, in the case that the engine **22** is operated together with the recirculation of the exhaust in a larger range than the preset high-load operation range above described.

In the hybrid vehicle **20** of the embodiment, it is determined whether the step angle θ of the stepper motor **163** is equal to the preset angle θ0 which corresponds to the totally closed state of the EGR valve **164** before driving and controlling the stepper motor **163** to open the EGR valve **164**, and the closing abnormality where the EGR valve **164** does not become in the totally closed state is accordingly detected. Instead, it may be determined whether the step angle θ of the stepper motor **163** is equal to the preset angle θ0 which corresponds to the totally closed state of the EGR valve **164** at the time of driving and controlling the stepper motor **163** to close the EGR valve **164**, and the closing abnormality may be accordingly detected. FIG. **6** is a flowchart showing an EGR valve closing time routine executed by the engine ECU **24**. In the EGR valve closing time routine, the CPU **24***a* drives and controls the stepper motor **163** so that the step angle θ of the stepper motor **163** becomes the preset angle θ0 (the stepper motor **163** becomes in the totally closed state) (step S**300**). The CPU **24***a* subsequently inputs the step angle θ of the stepper motor **163** from the step angle sensor **163***a* (step S**310**), and determines whether the input step angle θ of the stepper motor **163** is equal to the preset angle θ0 which corresponds to the totally closed state of the EGR valve **164** (step S**320**). When the step angle θ of the stepper motor **163** is equal to the preset angle θ0, the CPU **24***a* sets the abnormality detection flag Fa to value '0' (step S**330**). When the step angle θ of the stepper motor **163** is not equal to the preset angle θ0, the CPU **24***a* sets the abnormality detection flag Fa to value '1' (step S**340**). The CPU **24***a* then terminates the EGR valve closing time routine. In this case, the CPU **24***a* next may execute control to open the EGR valve **164** and execute the EGR execution time engine control routine of FIG. **4**, and this arrangement then has the same effect as the embodiment.

In the hybrid vehicle **20** of the embodiment, it is determined whether the step angle θ of the stepper motor **163** input from the step angle sensor **163***a* is equal to the preset angle θ0 which corresponds to the totally closed state of the EGR valve **164**, and the closing abnormality where the EGR valve **164** does not become in the totally closed state is accordingly detected. This is not essential. Any other arrangement may be applicable such as an arrangement of determining the EGR valve **164** is in the totally closed state, for example, an arrangement of detecting the closing abnormality based on any physical quantity (for example, the opening degree of the EGR valve **164**) other than the step angle θ of the stepper motor **163**.

In the hybrid vehicle **20** of the embodiment, the power of the motor MG**2** is converted by the reduction gear **35** and is output to the ring gear shaft **32***a*. The technique of the invention is also applicable to a hybrid vehicle **120** of a modified structure shown in FIG. **7**. In the hybrid vehicle **120** of FIG. **7**, the power of the motor MG**2** is output to another axle (an axle linked with wheels **64***a* and **64***b*) that is different from the axle connecting with the ring gear shaft **32***a* (the axle linked with the drive wheels **63***a* and **63***b*).

In the above embodiment, the invention is applied to and explained using a hybrid vehicle driven with power from an engine and power from motors. The invention may be applied to an automobile having an engine as a driving power source, other than hybrid vehicles.

It is possible to perform the same control as the embodiment in what is equipped with an internal combustion engine system primarily having the engine **22**, the EGR system **160**, and the engine ECU **24**. The principle of the invention may thus be actualized by an internal combustion engine system installed in diversity of other applications, for example, mobile bodies such as automobiles, other vehicles, boats and ships, and aircraft, and may also be installed in fixed equipments such as construction equipments. The principle of the invention may also be actualized by a control method of the internal combustion engine system.

The primary elements in the embodiment and its modified examples are mapped to the primary constituents in the claims of the invention as described below. The engine **22** in the embodiment corresponds to the 'internal combustion engine' in the claims of the invention. The EGR system **160** in the embodiment corresponds to the 'exhaust gas recirculation unit' in the claims of the invention. The catalytic converter **134** in the embodiment corresponds to the 'exhaust purification unit' in the claims of the invention. The engine ECU **24** executing the processing of step S**110** through S**130** in the EGR valve opening time routine of FIG. **3** to detect the closing abnormality when the step angle θ of the stepper motor **163** is not opened from the preset angle θ0 which corresponds to the totally closed state of the EGR valve **164** upon instruction to open the EGR valve **164** in the totally closed state corresponds to the 'closing abnormality detection module' in the claims of the invention. The engine ECU **24** executing the EGR execution time engine control routine of FIG. **4** to control the engine **22** using the set target fuel injection amount Qf* corresponds to the 'control module' in the claims of the invention. When the closing abnormality detection flag Fa is equal to value '0' (the closing abnormality where the EGR valve **164** does not become in the totally closed state is not detected) and the fuel increase determination flag Fi is equal to value '0' (the engine **22** is not operated in the preset high-load operation range where the purifying catalyst **134***a* has a possibility to be overheated), the basic fuel injection amount Qftmp is set as the target fuel injection amount Qf* during operation of the engine **22** with the recirculation of the exhaust gas. When the closing abnormality detection flag Fa is equal to value '0' and the fuel increase determination flag Fi is equal to value '1' (the engine **22** is operated in the preset high-load operation range where the purifying catalyst **134**_a_ has a possibility to be overheated), the product of the basic fuel injection amount Qftmp and the correction factor K (Qftmp·K) is set as the target fuel injection amount Qf* during operation of the engine **22** with the circulation of the exhaust gas. When the closing abnormality detection flag Fa is equal to value '1' (the closing abnormality is detected), the product of the basic fuel injection amount Qftmp and the correction factor K (Qftmp·K) is set as the target fuel injection amount Qf* during operation of the engine **22** with the circulation of the exhaust gas in the whole range that the engine **22** is operable together with the recirculation of the exhaust.

The 'internal combustion engine' is not restricted to the engine **22** designed to consume a hydrocarbon fuel, such as gasoline or light oil, and thereby output power, but may be an internal combustion engine of any other design, for example, a hydrogen engine. The 'exhaust gas recirculation unit' is not restricted to the EGR system **160** but may be any other unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a valve driver that drives the exhaust regulating valve to be open and close. The 'exhaust purification unit' is not restricted to the catalytic converter **134** but may be any other unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine. The 'closing abnormality detection module' is not restricted to the arrangement of detecting the closing abnormality when the step angle θ of the stepper motor **163** is not opened from the preset angle θ0 which corresponds to the totally closed state of the EGR valve **164** upon instruction to open the EGR valve **164** in the totally closed state, but may be any other arrangement of detecting a closing abnormality that the exhaust regulating valve does not become in a totally closed state, for example, an arrangement of detecting the closing abnormality when the step angle θ of the stepper motor **163** is not the preset angle θ0 which corresponds to the totally closed state of the EGR valve **164** while driving and controlling the stepper motor **163** so that the step angle θ of the stepper motor **163** becomes the preset angle θ0. The 'control module' is not restricted to the arrangement of, when the closing abnormality where the EGR valve **164** does not become in the totally closed state is not detected and the engine **22** is not operated in the preset high-load operation range where the purifying catalyst **134**_a_ has a possibility to be overheated, setting the basic fuel injection amount Qftmp as the target fuel injection amount Qf* during operation of the engine **22** with the recirculation of the exhaust gas, when the closing abnormality is not detected and the engine **22** is operated in the preset high-load operation range where the purifying catalyst **134**_a_ has a possibility to be overheated, setting the product of the basic fuel injection amount Qftmp and the correction factor K (Qftmp·K) as the target fuel injection amount Qf* during operation of the engine **22** with the circulation of the exhaust gas, when the closing abnormality is detected, setting the product of the basic fuel injection amount Qftmp and the correction factor K (Qftmp·K) as the target fuel injection amount Qf* during operation of the engine **22** with the circulation of the exhaust gas in the whole range that the engine **22** is operable together with the recirculation of the exhaust, but may be any other arrangement of controlling the internal combustion engine, upon no detection of the closing abnormality by the closing abnormality detection module, so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque, upon detection of the closing abnormality by the closing abnormality detection module, controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range.

The above mapping of the primary elements in the embodiment and its modified examples to the primary constituents in the claims of the invention is not restrictive in any sense but is only illustrative for concretely describing the modes of carrying out the invention. Namely the embodiment and its modified examples discussed above are to be considered in all aspects as illustrative and not restrictive.

There may be many other modifications, changes, and alterations without departing from the scope or spirit of the main characteristics of the present invention.

INDUSTRIAL APPLICABILITY

The technique of the invention is preferably applied to the manufacturing industries of the internal combustion engine systems and vehicles.

The invention claimed is:

1. A control method of an internal combustion engine system having an internal combustion engine, an exhaust gas recirculation unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a valve driver that drives the exhaust regulating valve to be open and close, and an exhaust purification unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine, the control method of the internal combustion engine system comprising:

upon no occurrence of a closing abnormality that the exhaust regulating valve does not become in a totally closed state, controlling the internal combustion engine so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque,

upon occurrence of the closing abnormality controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range.

2. An internal combustion engine system having an internal combustion engine, an exhaust gas recirculation unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a valve driver that drives the exhaust regulating valve to be open and close, and an exhaust purification unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine, the internal combustion engine system comprising:

a closing abnormality detection module that detects a closing abnormality that the exhaust regulating valve does not become in a totally closed state; and

a control module that controls the internal combustion engine, upon no detection of the closing abnormality by the closing abnormality detection module, so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque,

upon detection of the closing abnormality by the closing abnormality detection module, the control module controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range.

3. The internal combustion engine system in accordance with claim **2**, wherein the valve driver is a stepper motor, and

the closing abnormality detection module detects the closing abnormality when a step angle of the stepper motor is not a step angle corresponding to the totally closed state of the exhaust regulating valve regardless of an instruction to totally close the exhaust regulating valve, or when the step angle of the stepper motor is not opened more from the step angle corresponding to the totally closed state of the exhaust regulating valve regardless of an instruction to open the exhaust regulating valve from the totally closed state.

4. The internal combustion engine system in accordance with claim **2**, wherein the preset range is a whole range that the internal combustion engine is operable while the internal combustion engine is operated together with the recirculation of the exhaust.

5. A vehicle having an internal combustion engine capable of outputting power for driving the vehicle, an exhaust gas recirculation unit including an exhaust regulating valve that regulates a recirculation amount of exhaust of the internal combustion engine into an intake system of the internal combustion engine and a valve driver that drives the exhaust regulating valve to be open and close, and an exhaust purification unit including an exhaust purifying catalyst that purifies the exhaust of the internal combustion engine, the vehicle comprising:

a closing abnormality detection module that detects a closing abnormality that the exhaust regulating valve does not become in a totally closed state; and

a control module that controls the internal combustion engine, upon no detection of the closing abnormality by the closing abnormality detection module, so that the internal combustion engine is operated with fuel injection where a fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with recirculation of the exhaust in a high-load operation range that is a range of rotation speeds more than or equal to a preset rotation speed and torques more than or equal to a preset torque,

upon detection of the closing abnormality by the closing abnormality detection module, the control module controlling the internal combustion engine so that the internal combustion engine is operated with the fuel injection where the fuel increase is performed to prevent that the exhaust purifying catalyst is overheated, in a case that the internal combustion engine is operated together with the recirculation of the exhaust in a preset range that is a larger range than the high-load operation range.

6. The vehicle in accordance with claim **5**, wherein the valve driver is a stepper motor, and

the closing abnormality detection module detects the closing abnormality when a step angle of the stepper motor is not a step angle corresponding to the totally closed state of the exhaust regulating valve regardless of an instruction to totally close the exhaust regulating valve, or when the step angle of the stepper motor is not opened more from the step angle corresponding to the totally closed state of the exhaust regulating valve regardless of an instruction to open the exhaust regulating valve from the totally closed state.

7. The vehicle in accordance with claim **5**, wherein the preset range is a whole range that the internal combustion engine is operable while the internal combustion engine is operated together with the recirculation of the exhaust.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

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APPLICATION NO. : 12/988970
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INVENTOR(S) : Hikikazu Akimoto

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column	Line	
14	37	Change "to be open and close" to --to be opened and closed--.
14	66-67	Change "to be open and close" to --to be opened and closed--.
16	3	Change "to be open and close" to --to be opened and closed--.

Signed and Sealed this
Thirteenth Day of December, 2011

David J. Kappos
Director of the United States Patent and Trademark Office